

# The Land-Sea Warming Contrast as the Driver of Tropical Sea Level Pressure Changes

Tobias Bayr and Dietmar Dommenges

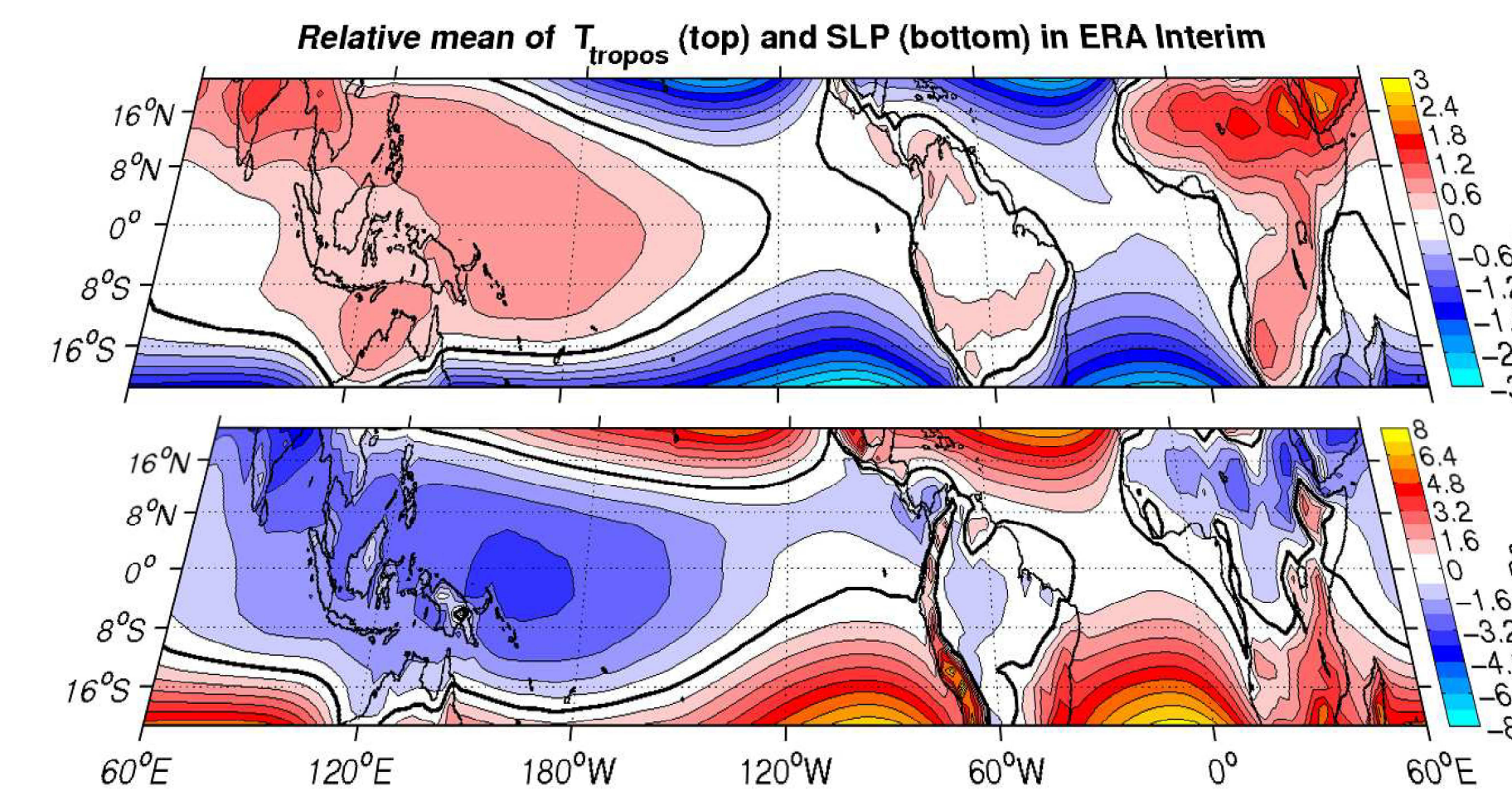


## Abstract

In this poster we address the causes of the large-scale tropical sea level pressure (*SLP*) changes during climate change. The analysis is based on climate change model simulations, observed trends and the seasonal cycle. In all three cases the regional changes of tropospheric temperature ( $T_{tropos}$ ) and *SLP* are strongly related to each other (considerably stronger than (sea) surface temperature and *SLP*). This relationship basically follows the Bjerknes Circulation Theorem, with relatively low regional *SLP* where we have relatively high  $T_{tropos}$  and vice versa. A simple physical model suggests a tropical *SLP* response to horizontally inhomogeneous warming in the tropical  $T_{tropos}$ , with a sensitivity coefficient of about  $-1.7 \text{ hPa/K}$ . This relationship explains a large fraction of observed and predicted changes in the tropical *SLP*.

It is shown that in climate change model simulations the tropical land-sea warming contrast is the most significant structure in the regional  $T_{tropos}$  changes relative to the tropical mean changes. Since the land-sea warming contrast exists in the absent of any atmospheric circulation changes it can be argued that the large-scale response of tropical *SLP* changes is to first order a response to the tropical land-sea warming contrast, with decreasing *SLP* over the sector of strongest warming (South America to Africa) and increasing *SLP* elsewhere, which is roughly the Indo-Pacific warm pool region. As *SLP* changes and changes in atmospheric circulation go hand in hand, these results suggest an increase in the potential for deep convection conditions over the Atlantic Sector and a decrease over the Indo-Pacific warm pool region in the future.

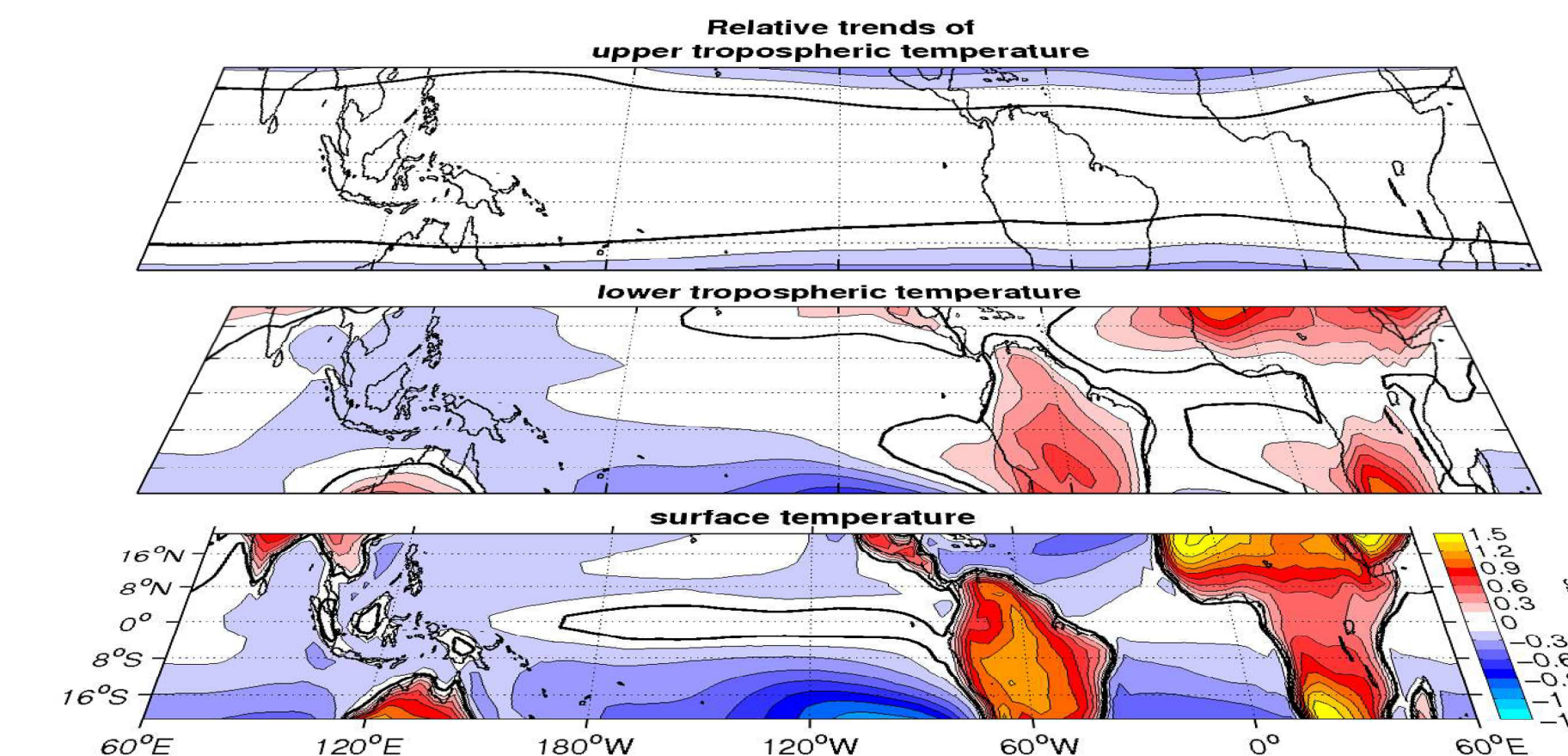
## Introduction



**Figure 1:** Annual mean  $T_{tropos}$  (top) and *SLP* (bottom) in ERA Interim relative to the tropics area total mean ( $-9.8^\circ\text{C}$  in  $T_{tropos}$  and  $1012 \text{ hPa}$  in *SLP*); pattern correlation between these two pattern is  $-0.86$ .

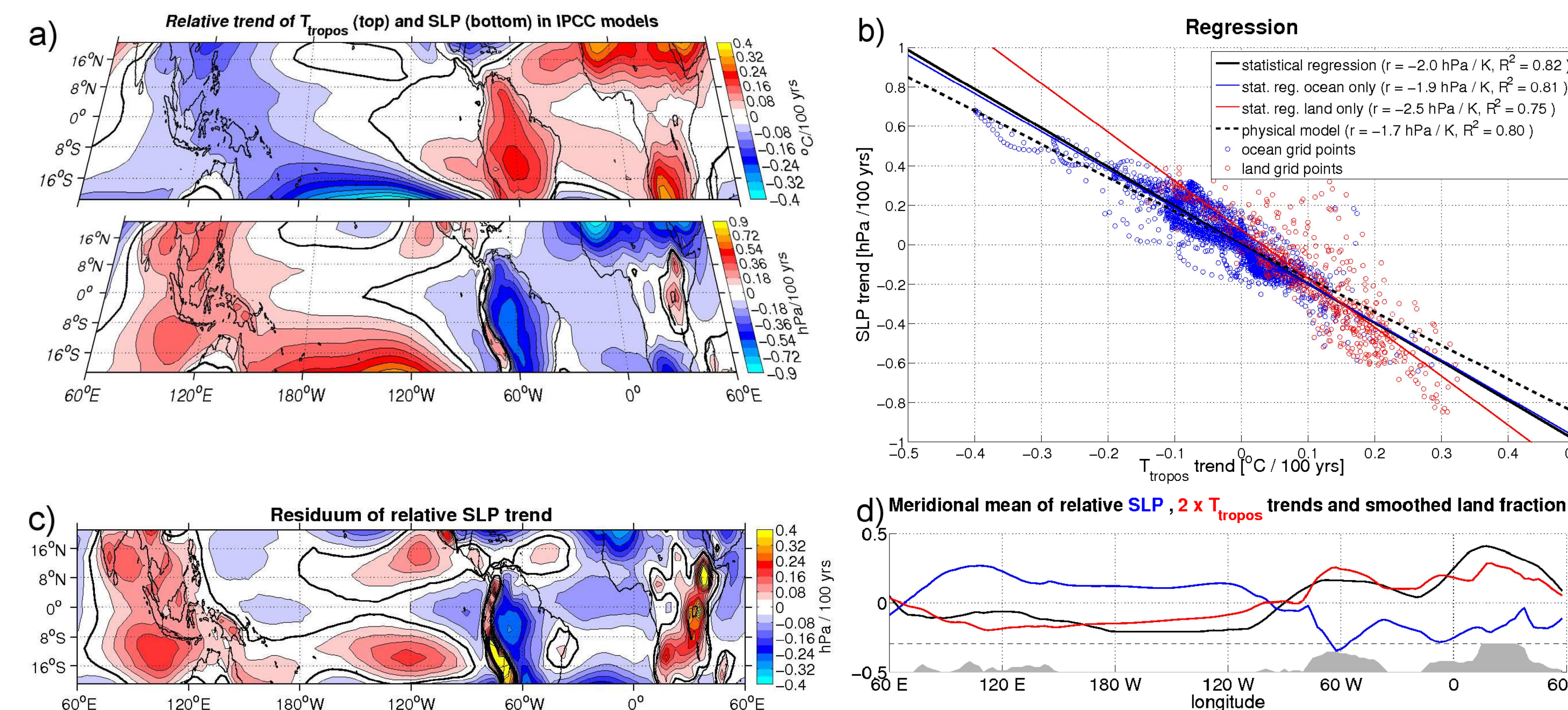
## Simple thought experiment:

In today's climate there are three relatively warm places in the tropics (Indo-Pacific warm pool region, South America and Africa), where the main deep convection takes place and *SLP* is low (Fig. 1). In climate change projections due to land-sea warming contrast two of the three warm places (Africa and South America) warm stronger than the third one (Indo-Pacific warm pool region, see Fig. 2 surface and lower troposphere), because highly available moisture reduces the warming there. Having the strong inverse relationship between  $T_{tropos}$  and *SLP* in mind we would expect from this little thought experiment that on large scale the *SLP* will increase over the warm pool region and decrease over Africa and South America, if land-sea warming contrast is the dominant feature in the *SLP* trends.



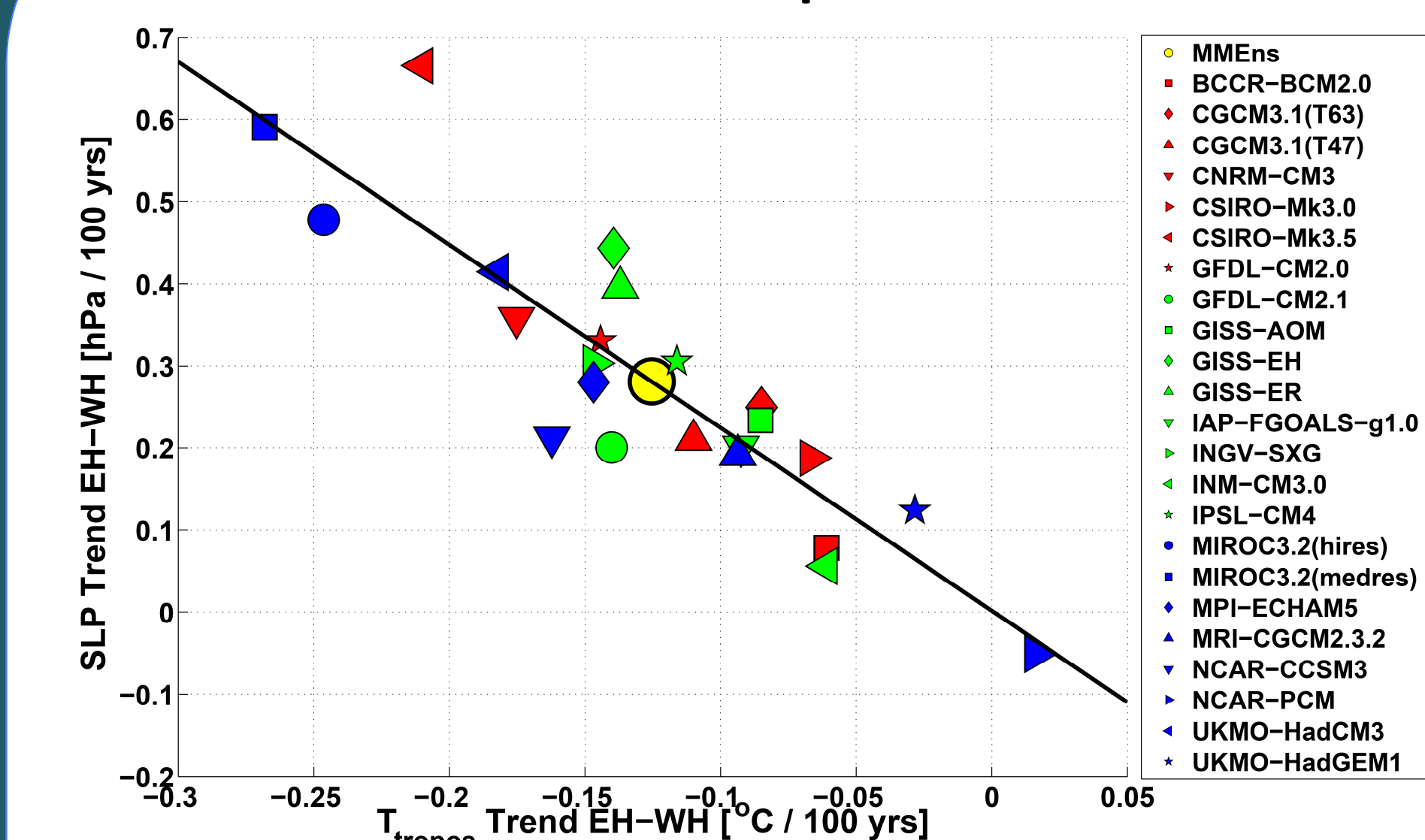
**Figure 2:** Linear trend of IPCC multi model ensemble for the period 1970 to 2099 for surface temperature, lower tropospheric temperature (925 to 500 hPa) and upper tropospheric temperature (500 to 100 hPa); area mean trend of  $2.4^\circ\text{C}/100 \text{ yrs}$ ,  $3.0^\circ\text{C}/100 \text{ yrs}$  and  $4.4^\circ\text{C}/100 \text{ yrs}$  respectively (from bottom to top) removed.

## IPCC model results



**Figure 3:** (a) as Fig. 1 but for linear trend of the IPCC multi model ensemble for the period 1970 to 2099; area mean trend removed ( $3.6^\circ\text{C}/100 \text{ yrs}$  for  $T_{tropos}$  and  $0.05 \text{ hPa}/100 \text{ yrs}$  for *SLP*); pattern correlation is  $-0.90$ ; (b) regression of the two trend pattern in (a); (c) residuum of relative *SLP* trend after applying the physical model to multi model ensemble data, (d) meridional mean of the two trend pattern in (a) and land fraction of the area between  $23.5^\circ\text{S}$  and  $23.5^\circ\text{N}$  in black, smoothed with a running mean of  $60^\circ$  and mean value subtracted; the grey filled area is the unsmoothed meridional mean of land fraction, with y-axis on the right.

## IPCC model comparison

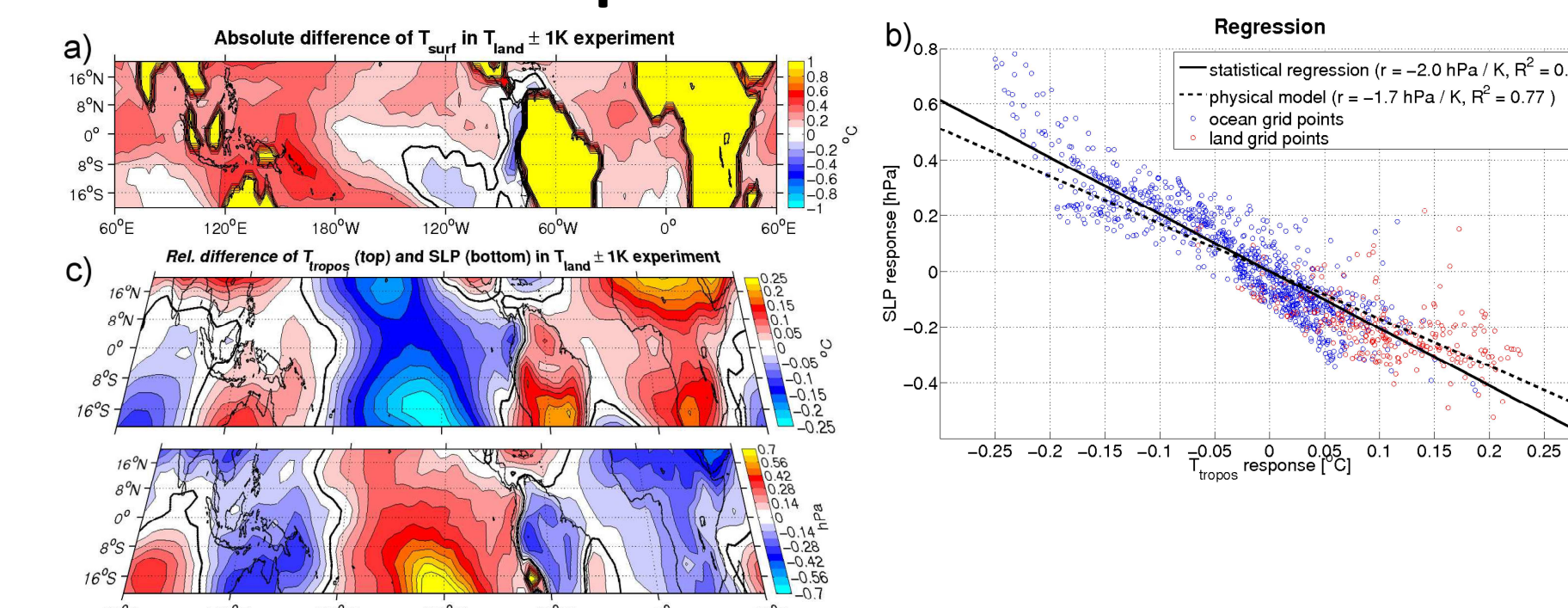


**Figure 4:** Comparison of the "eastern" hemispheric ( $60^\circ\text{E}-120^\circ\text{W}$ ,  $23.5^\circ\text{S}-23.5^\circ\text{N}$ ) minus "western" hemispheric ( $120^\circ\text{W}-60^\circ\text{E}$ ,  $23.5^\circ\text{S}-23.5^\circ\text{N}$ ) trend of  $T_{tropos}$  (on x-axis) and *SLP* (on y-axis) of the individual IPCC models; the black line is the regression line with  $R^2 = 0.79$ .

## Conclusion:

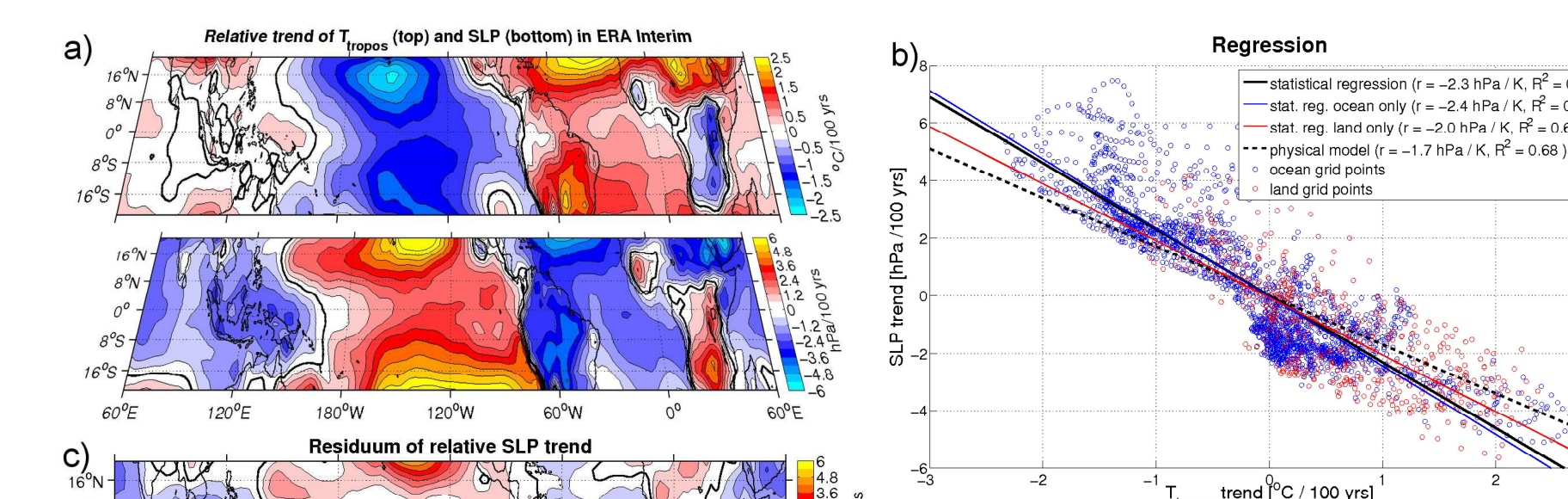
- Inverse relationship between  $T_{tropos}$  and *SLP* is observable in nearly all IPCC models (as in Fig. 3a).
- In most IPCC models is land-sea warming contrast the driver of the large scale *SLP* trends, with decreasing *SLP* over the region from South America to Africa and increasing *SLP* elsewhere (Fig. 4).
- Idealised experiments confirm our hypothesis (Fig. 5).
- Observations show a strong inverse relationship between  $T_{tropos}$  and *SLP*, but land-sea warming contrast is probably not the dominant driver (Fig. 6).

## Idealised experiments



**Figure 5:** (a) absolute difference of  $T_{surf}$  in the idealised  $T_{land} \pm 1\text{K}$  experiment; (b) and (c) as Fig. 3a-b, but here the relative difference of the idealised experiment, area mean response of  $0.6^\circ\text{C}$  for  $T_{tropos}$  and  $-0.05 \text{ hPa}$  for *SLP* removed, pattern correlation =  $-0.89$ .

## Observations



**Figure 6:** as Fig. 3 but here for the ERA Interim reanalysis data in the period 1989 to 2010; area mean trend removed in (a):  $1.7^\circ\text{C}/100 \text{ yrs}$  for  $T_{tropos}$  and  $-1.2 \text{ hPa}/100 \text{ yrs}$  for *SLP*.